

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

APPLICATION FOR UNITED STATES LETTERS PATENT

TITLE OF THE INVENTION

HOLLOW FIBER CARBONATION

INVENTOR

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1 **TECHNICAL FIELD OF THE INVENTION**

2 This invention relates generally to beverage dispensing, and in particular to methods and
3 apparatus for carbonating beverages.

4

5 **BACKGROUND OF THE INVENTION**

6 In "post-mix" beverage dispensing, beverage syrups are mixed with plain or carbonated
7 water to form finished beverages. Carbonation has proved to be one of the more difficult areas
8 in post-mix dispensing. For example, carbonation systems are relatively expensive and can
9 present significant maintenance and reliability issues.

10 Therefore, a need has arisen for a less expensive, high quality, and more reliable
11 carbonation system.

12 **SUMMARY OF THE INVENTION**

13 In accordance with the teachings of the present invention, methods and apparatus for
14 carbonating beverages are provided which substantially eliminate or reduce problems associated
15 with prior art systems.

16 In a particular embodiment, a beverage dispenser is provided that includes a water supply
17 (that may or may not comprise treated water), a CO₂ source, and a carbonator coupled to the
18 water supply and the CO₂ source. The carbonator includes at least one hydrophobic hollow fiber
19 proximate to which water is carbonated. Also included is a beverage syrup source, such that
20 beverage syrup and carbonated water are dispensed to form finished drinks. In one particular
21 embodiment, the hydrophobic hollow fiber comprises polypropylene.

1 In particular embodiments, CO₂ is supplied through one or more hollow fibers, and water
2 flows across the outside of one or more of the hollow fibers. In an alternative embodiment,
3 water is supplied through one or more of the hollow fibers.

4 It is advantageous to include a water treatment system, such that the water supply
5 comprises treated water. It is particularly advantageous for the water treatment system to
6 comprise a reverse osmosis water treatment system. In another embodiment, a reservoir is
7 coupled to a reverse osmosis water treatment system and the carbonator.

8 Plain water circuits may also be included with the various embodiments, such that both
9 carbonated and non-carbonated beverages may be produced.

10 In one embodiment, a pre-carbonator is coupled to the carbonator to pre-carbonate water
11 before further carbonation in the carbonator. The pre-carbonator may comprise a plurality of
12 hollow fibers.

13 In particular embodiments, a reservoir may be coupled to the pre-carbonator, or to the
14 carbonator (whether or not a pre-carbonator is used), to hold carbonated water.

15 Methods of dispensing beverages are provided that comprise supplying water, supplying
16 CO₂, carbonating the water with the CO₂ proximate to a plurality of hydrophobic hollow fibers,
17 and dispensing carbonated water and beverage syrup to form finished drinks. The methods may
18 also include treating the water, for example through reverse osmosis. Also, the methods may
19 include pre-carbonating the water before carbonating it.

20 In particular methods, the treated water is stored before carbonating. Also, non-
21 carbonated water may be dispensed, such that both carbonated and non-carbonated beverages
22 may be produced.

1 Important technical advantages of the present invention include, among other advantages,
2 reducing the cost of dispensers; increasing the efficiency and reliability of carbonation; and
3 increasing beverage quality due to the use of treated water and better carbonation.

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5 **BRIEF DESCRIPTION OF THE DRAWINGS**

6 Reference is made in the description to the following briefly described drawings, wherein
7 like reference numerals refer to corresponding elements:

8 FIGURE 1 illustrates an embodiment of a carbonation system with water treatment
9 according to the teachings of the present invention;

10 FIGURE 2 illustrates an embodiment of a pre-carbonation and finishing carbonation
11 combination according to the teachings of the present invention;

12 FIGURE 3 illustrates an embodiment of a hollow fiber carbonator according to the
13 teachings of the present invention;

14 FIGURE 4 illustrates another embodiment of a hollow fiber carbonator according to the
15 teachings of the present invention;

16 FIGURE 5 illustrates one embodiment of a pre-carbonation system according to the
17 teachings of the present invention;

18 FIGURE 6 illustrates one embodiment of a treated water source according to the
19 teachings of the present invention;

20 FIGURE 7 illustrates a particular embodiment of an integrated source of plain treated
21 water for use with beverage dispensing; and

22 FIGURE 8 illustrates another embodiment according to the teachings of the present
23 invention in which a pre-carbonation circuit forms a reservoir for supply of treated water.

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2 **DETAILED DESCRIPTION OF THE INVENTION**
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4 FIGURE 1 illustrates a dispensing system 10 that includes a hollow fiber carbonator 12
5 according to the teachings of the present invention. Hollow fiber carbonator 12, which will be
6 discussed in detail in connection with FIGURES 3 and 4, comprises one or more (preferably a
7 bundle of) hollow fibers made of a hydrophobic material, such as polypropylene. Carbonation
8 occurs by molecular gas transfer of CO₂ into the water.

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14 Preferably, water is first treated in treatment system 14. However, water may be taken
15 directly from a water supply without treating it in a treatment system. Treatment system 14 can
16 be any water treatment system, but preferably is a reverse osmosis (“R/O”) system. Thin film
17 composite membranes (“TFC”) or thin film membranes (“TFM”) such as those made by the Dow
18 Chemical Company under the trademark Filmtec, may be used as the R/O membrane. However,
19 this is illustrative only, and any R/O device may be used.

20
21 Treated water is cooled in the dispenser 10 via chiller unit 16. Chiller unit 16 may be a
22 cold plate, through with the water is circulated and cooled because of contact of the cold plate
23 with ice. As another example, the chilling unit 16 may be an ice/water bath created by a
24 mechanical refrigeration unit, such as a vapor compression system. However, it should be
25 understood that any cooling system may be used for chilling unit 16, including, for example by
26 way of illustration only and not by way of limitation, a system based on Stirling cycle
27 refrigeration.

28
29 Chilled water is pumped via pump 18 to the hollow fiber carbonator 12. The CO₂
30 supplied to the carbonator 12 is provided by CO₂ source 20 which may comprise a tank of CO₂
31 gas. Carbonated water, also called “soda,” is transmitted from the hollow fiber carbonator 12 to

1 dispensing valves 22. Dispensing valves 22, in response to requests for beverages, open to
2 transmit soda to nozzles 24, which facilitate mixing of the water with beverage syrups and/or
3 beverage flavors to form finished drinks. Instead of valves 22, metering pumps or other devices
4 for dispensing may be used, without departing from the intended scope of the present invention.

5 As shown in FIGURE 1, a plain water circuit 26 is also provided, in which plain water is
6 transmitted to the valves 22 around the carbonator 12. In this way, the dispensing unit 10 allows
7 for the dispensing of both carbonated beverages (with soda created through the carbonator 12
8 and transmitted to the valves 22) and plain water beverages, such as teas or juices (with plain
9 water transmitted to the valves 22 via plain water circuit 26).

10 With the present invention, significant advances result from the use of hydrophobic
11 hollow fiber carbonator 12. In particular, efficient carbonation occurs at either low pressures or
12 high pressures, because of the use of the hydrophobic material in the hollow fibers of carbonator
13 12. The ability to carbonate at low pressures can significantly reduce the costs of the dispenser
14 10. Furthermore, the combination of the hollow fiber carbonator 12 and the water treatment unit
15 14 provides for extremely efficient carbonation. In particular, the use of R/O treatment creates
16 water that is very efficiently carbonated with the hollow fiber carbonator 12.

17 FIGURE 2 illustrates another embodiment of the present invention in which a pre-
18 carbonation circuit 28 is provided. Pre-carbonation circuit 28 provides a supply of soda at a
19 carbonation level lower than that required for some or all of the carbonated beverages to be
20 dispensed. For example, if the most highly carbonated beverage includes five volumes of
21 carbonation, then pre-carbonation circuit 28 may provide, as an example, a carbonation level of
22 2.5 volumes. However, it should be understood that this is an example only, and any carbonation
23 level may be provided by pre-carbonation circuit 28. In the embodiment of FIGURE 2,

1 carbonator 12 acts as a finishing carbonation unit, further carbonating water from the pre-
2 carbonation circuit 28.

3 As is shown in FIGURE 2, the plain water circuit 26 runs parallel to the pre-carbonation
4 circuit 28, to provide plain water to the valves 22 for plain water finished beverages. Also
5 shown in FIGURE 2 is a lower-carbonation level circuit 30 that runs parallel to carbonator 12.
6 The lower-carbonation level circuit 30 provides soda to the valves 22 at a lower carbonation
7 level than that provided by carbonator 12. Thus, with the system shown in FIGURE 2, valves 22
8 can receive plain water, or soda carbonated at at least two different levels, as provided by circuit
9 30 or through carbonator 12.

10 Moreover, different levels of carbonation can be provided by mixing varying amounts of
11 plain water with varying amounts of the soda provided by circuit 30 or carbonator 12 (whether or
12 nor a pre-carbonation circuit is used). As another alternative, the carbonation level from
13 carbonator 12 may be varied by adjusting the carbonation pressure provided by carbonation
14 supply 20. For example, a variable regulator may be provided to adjust the pressure depending
15 on carbonation required.

16 FIGURE 3 illustrates a particular embodiment of carbonator 12. As shown in FIGURE 3,
17 the carbonator 12 preferably includes a bundle of individual hollow fibers 32. CO₂ is supplied to
18 these hollow fibers and runs through the hollow core of the fibers 32. Water is supplied between
19 the individual fibers, and can be supplied at any angle to the bundle, including tangentially to the
20 bundle or parallel to the bundle. Carbonation occurs by molecular gas transfer through the
21 hydrophobic fibers.

22 FIGURE 4 illustrates an alternative configuration of carbonator 12, in which the water is
23 supplied through the cores of the hollow fibers 32, and CO₂ is supplied between the individual

1 fibers of the bundle. Thus, in FIGURE 4, water flows through the fibers, with CO₂ supplied
2 outside of the fibers. Again, carbonation occurs through molecular gas transfer.

3 Examples of hollow fiber membranes suitable for use with the present invention are
4 provided by Celgard Inc., under the trademark Liqui-Cel®. While a bundle of hollow fibers is
5 preferred, the carbonator may be configured as one or more fibers. For example, but not by way
6 of limitation, one fiber may be used that is wound or laid out back and forth, or in a mesh or net
7 pattern, to create sufficient surface area for the desired level of carbonation.

8 FIGURE 5 illustrates a particular embodiment of pre-carbonation circuit 28. As shown in
9 FIGURE 5, pre-carbonation circuit 28 includes a pump 34, a hollow fiber carbonator 36 coupled
10 to a CO₂ source 20, and a reservoir 38 coupled between the output of carbonator 36 and the input
11 of pump 34. The reservoir 38 is preferably a flexible laminate bag capable of retaining
12 carbonation. A relief valve 40 may be coupled to reservoir 38 to relieve pressures. In operation,
13 water from the chiller unit 16 is provided to the pre-carbonation circuit 28. Pump 34 pumps the
14 cold water through the carbonator 36, which may be configured, for example, as shown in
15 FIGURE 3 or FIGURE 4. The carbonated water output from the carbonator 36 is stored in the
16 reservoir 38. The pre-carbonation circuit 38 creates a reservoir of pre-carbonated water for
17 dispensing. This reservoir is important in connection with the use of R/O systems, as it allows
18 storage of treated water during lower use periods, thus allowing for smaller R/O systems than
19 would be required if treated R/O water were supplied on demand.

20 The pre-carbonation circuit 28 operates continuously until the reservoir 38 is full, at
21 which time the pump 34 is shut off. In a particular example, a proximity switch 42 may be used
22 to control the pump 34. When the bag of reservoir 38 is full, it will physically contact the
23 proximity switch, thus resulting in a signal that turns off the pump 34. It should be understood

1 that other sensors may be used to regulate the volume of the reservoir, including floats. Also,
2 other reservoirs, such as permanent tanks, may be used. However, it is preferable to use a bag
3 and an external switch or sensor to minimize contamination of the water. With the pre-
4 carbonation circuit 28 shown in FIGURE 5, a reservoir of carbonated water is provided, thus
5 allowing for high volume dispensing with a low volume R/O unit. Therefore, costs are greatly
6 reduced over alternative configurations.

7 The output of the carbonator 36 and the reservoir 38 may be sent to valves 22 or finishing
8 carbonator 12, or may be sent there through a cooling coil located in proximity to the chilling
9 unit 16, so as to chill the water from the reservoir 38 before dispensing. Check valves 35 and 39
10 may be provided to prevent backflow (backflow prevention may be included in other
11 embodiments, as well, if desired).

12 FIGURE 6 illustrates a particular embodiment of water treatment system 14. As shown
13 in FIGURE 6, water treatment system 14 may include a water treatment unit 44, such as an R/O
14 unit as discussed above, and a reservoir 46. The reservoir 46 is preferably a bag with a volume
15 regulation sensor, such as that discussed above in connection with FIGURE 5. With the
16 configuration shown in FIGURE 6, a reservoir of plain water is provided for supply to the
17 beverage dispenser 10. In a preferred embodiment, the water treatment system 14 is built in as
18 part of the dispensing unit 10; however, all or part of the water treatment system 14 may be
19 separate from the dispenser 10. By using reservoir 46, a relatively small treatment unit, and in
20 particular a small R/O unit, may be used, thus lowering the costs from those that would be
21 expended if an R/O unit were configured to supply water on demand. Also, systems other than
22 or in addition to an R/O unit may be used, including, without limitation, pre-filter carbon filter
23 systems.

1 In particular embodiments, the water treatment system may comprise some or all of the

2 elements and advantages of those disclosed in pending United States patent application Nos.

3 09/912,868 (filed July 25, 2001), 09/773,381 (filed January 31, 2001), and 09/775,116 (filed

4 February 1, 2001), entitled "Self Cleaning Pre-Filter System," "Microbial Resistant Water

5 Purification and Collection System," and "Constant Pressure Filtered Water Delivery System,"

6 respectively, all of which are commonly owned by the assignee or inventor of the present

7 application, and which are herein expressly incorporated by reference, in their entirety.

8 The reservoir 46 may be regulated by a sensor that senses when the reservoir is full, to

9 turn off the water treatment unit 44. The preferred embodiment of reservoir 46 is a flexible

10 plastic laminate bag, with an external sensor for regulating volume. The use of a flexible bag

11 reduces contamination issues and provides other advantages, such as lower costs and easy

12 cleaning, since the flexible bag can be replaced periodically, if necessary. United States Patent

13 Nos. 5,256,279 and 5,927,099, which are herein incorporated by reference in their entirety,

14 disclose particular combinations of water treatment systems with flexible bags that may be used,

15 among others, as particular embodiments of a water treatment system in the present invention.

16 However, any reservoir, such as a permanent tank, and internal or external sensors, may also be

17 used.

18 FIGURE 7 illustrates a more detailed example of a particular water supply system for

19 beverage dispensing 10. In the particular example of FIGURE 7, the chilling unit is a vapor

20 compression refrigeration unit that includes condenser 50 and evaporator 52. A compressor 54

21 pumps refrigerant from the evaporator 52 to the condenser 50. Water is provided to R/O system

22 56 from an external water supply, such as a municipal supply. In a particular embodiment, the

23 inlet water is transmitted through a coil 58 located in close proximity to condenser 50. This

1 approach preheats the water to the R/O system 56, improving the efficiency of the R/O unit, and
2 also improving the efficiency of the refrigeration unit by assisting in condensation across
3 condenser 50. Similarly, the reject water from R/O unit 56 may be passed through coil 60 to
4 assist in condensation across condenser 50. However, it should be understood that
5 these circuits 58 and 60 are exemplary only, and need not be included. While pre-heating the
6 inlet water assists in R/O treatment efficiency, it then requires further cooling of the water by
7 evaporator 52. Thus, a balance should be made between the most efficient use of energy and
8 water, depending on the demands of the application. In most cases, overall efficiency should be
9 improved by using reject water from the R/O unit 56 to assist in condensation across condenser
10 50.

11 Treated water from the R/O unit 56 is stored in reservoir 62, which may be a reservoir
12 such as that discussed above in connection with reservoir 46 of FIGURE 6 (water may also flow
13 back for back flushing of the unit 56). In a preferred embodiment, the reservoir 62 is located in
14 proximity to evaporator 52, to cool the water within the reservoir 62. Water to be dispensed for
15 carbonated or plain water drinks is drawn from the reservoir 62 through circuit 64 which is
16 cooled by evaporator 52. The system of FIGURE 7 provides the advantages discussed above in
17 connection with FIGURE 6, in that a relatively small R/O unit may be used because of the
18 storage reservoir 62. Furthermore, by placing the reservoir 62 in close proximity to the
19 evaporator 52, relatively high quantities of cold water are available.

20 Although the refrigeration unit shown in FIGURE 7 is a vapor compression system, a
21 similar configuration can be used in connection with an ice-cooled cold plate. The evaporator 52
22 would represent a cold plate, and the reservoir 62 would be located in close proximity to the cold

1 plate. With an ice-cooled cold plate, obviously the condenser and pump shown in FIGURE 7 are
2 not needed.

3 FIGURE 8 illustrates another embodiment of the present invention in which a reservoir
4 70 is coupled to a carbonation circuit such as that shown in FIGURE 5. With the configuration
5 of FIGURE 8, the reservoir provides a source of soda. Reservoir 70 of FIGURE 8 is located in
6 close proximity to the evaporator 52, and is coupled to a pump 72 and hollow fiber carbonator
7 74, similar to the carbonation circuit discussed above in connection with FIGURE 5.

8 As shown in FIGURE 8, plain treated water is sent through a cooling coil 76 in proximity
9 to evaporator 52 (which may also represent a cold plate) and either bypasses or supplies the
10 carbonation circuit. The bypass circuit leads to the valves for production of finished beverages.
11 Also, the output of the reservoir 70 and carbonator 74 may be transmitted directly to the valves
12 or to a finishing CO₂ carbonator, and may be sent there through a coiling cool that runs in
13 proximity to evaporator 52 (or a cold plate). The volume of water in the reservoirs of both
14 FIGUREs 7 and 8 may by controlled, as discussed above, through use of an external proximity
15 switch that shuts off flow to the reservoir when sufficiently full. Other control regimes may also
16 be used.

17 Although not shown in the figures, an electronic control system is provided for
18 controlling operation of the various embodiments discussed herein. The control system may
19 include a microprocessor or microcontroller, and various input/output ports to effect the control.
20 The control system interfaces with the sensors to control operation of the water treatment units,
21 pumps, and any other electronically controlled elements (such as, without limitation, variable
22 regulators). Furthermore, the control system interfaces with a customer interface for turning on
23 valves to dispense the desired beverages, and for dispensing ice, if ice dispensing is included.

1 The particular descriptions provided are illustrative examples, and features and
2 advantages of each example can be interchanged with, or added to the features and advantages in
3 the other embodiments and examples herein. For example, the embodiments discussed in
4 connection with pre-carbonation may be used alone without a need for a finishing carbonation
5 stage – i.e., the pre-carbonator is the carbonator.

6 And, in general, although the present invention has been described in detail, it should be
7 understood that various changes, alterations, substitutions, additions and modifications can be
8 made without departing from the intended scope of the invention, as defined in the following
claims.